SUMMARY

Cotton production is changing under the steadily increasing pressures of mechanization. Research is being called upon to develop the tools and methods of mechanization to make production more efficient.

All fields of research on cotton are affected, including plant breeding, land arrangement and soil care, crop residue disposal, seedbed preparation, planting, fertilization, weed and grass control, insect control, disease control, defoliation, harvesting, farm machinery development, and ginning methods.

In addition, the national pattern of cotton production is changing as emphasis shifts toward areas better suited to mechanization and away from areas that cannot readily mechanize.

Already, mechanization and related technical advances have cut 2 billion man-hours off the annual labor requirement to produce the nation's cotton crop, and have doubled the productive capacity of the individual cotton farmer. Yet cotton mechanization is far from complete. For instance, only 20 to 25 percent of the crop is being mechanically harvested, and in the humid areas up to 30 hours of man labor per acre are required for weed control.

This report deals with the impact of mechanization on cotton production practices and what research is doing to make the mechanized operation more efficient. It points out the complicated and interrelated problems confronting research scientists and the need for a team approach in finding practical solutions that will help to improve the competitive position of cotton in domestic and world markets.

CONTENTS

Information in this report was supplied by the Agricultural Engineering Research Branch, Entomology Research Branch, Field Crops Research Branch, Production Economics Research Branch of the Agricultural Research Service, State research reports, and State and regional reports of work conducted in cooperation with the Agricultural Research Service

THE IMPACT OF MECHANIZATION ON COTTON PRODUCTION

Mechanization during the past 25 years has created a major revolution in cotton production. Methods and machines are still changing under the pressure to achieve total mechanization and to place cotton in a position to compete realistically in the textile market. These changes, which are interrelated, are having a direct effect on the agricultural, economic, and even social structures of the Cotton Belt.

Mechanization has helped to cut 2 billion hours off the man-labor required to grow the nation's cotton crop. It has been an integral part of the technical advances that more than doubled the productive capacity of the cotton farmer. At the same time, cotton farming is becoming a more complex business, and requires additional capital investment as machines are added. Furthermore, the pattern of cotton production across the country is changing. Major production is shifting to those farms and areas that are best adpated to mechanization and away from those not suited to the new practices.

The entire process of mechanization is built upon the results of agricultural research, both public and private. The resources of research are being hard pressed to provide the solutions to problems of mechanization as fast as they are needed in the cotton fields and gins. Some of the solutions have been found. Others have not. Sometimes the need is so great that preliminary findings are put to use before they are properly tested. The progress that has already been made is impressive. Many needs for future work, however, are clearly discernible.

MECHANIZATION DEFINED

According to one possible definition, cotton mechanization started with the development of the cotton gin late in the eighteenth century. Replacement of hand labor by machinery actually started at that time. But for more than a hundred years after that, cotton farming was still operated by man and mule power. There was no substitute for hand labor to hoe, cultivate, and harvest a cotton crop.

When the row-crop tractor appeared in the 1920's, it helped to reduce labor requirements for plowing and cultivation. At the same time, it created new problems. One man could grow more cotton than he and his family could harvest. As the number of tractors increased, the pattern of cotton production turned away from the share-cropper system toward a greater use of day laborers, and the need became greater for speeding the development of a practical mechanical harvester.

The introduction of the mechanical harvester was the starting point of mechanized cotton production as it is generally understood today. The harvester set the fast pace of the evolution to new methods and machines. If the harvester was to be efficient, other machines and practices had to be developed and adapted to its needs. The direction of research was shifted in line with these needs.

Introduction of the mechanical harvester solved some problems, but brought many new ones. More foreign matter, immature bolls, and other debris were taken to the gin. Moisture content of the cotton was increased by the use of water to dampen picking spindles. Therefore, ginning processes had to be revised. In fact, the burden is on the gin to make mechanical harvesting economically feasible. The excessive amounts of foreign matter and moisture, which range as high as 250 pounds per bale for mechanical picking and 1,700 pounds for mechanical stripping, must be removed at the gin to obtain grades which will make these harvesting practices profitable.

Defoliants and desiccants became important to permit efficient use of harvesting machines and to maintain the quality of the harvested cotton. New plant types to provide proper boll distribution, new methods of planting, better weed control, earlier insect control--all these and many more are being developed to provide for a uniformly maturing crop that is necessary for efficient machine harvesting.

Cotton mechanization, then, is more than putting machines into the fields. It encompasses all the aspects of production including plant breeding, field arrangement and soil care, crop residue disposal, seedbed preparation, planting, fertilization, weed and grass control, insect control, disease control, defoliation, harvesting, farm machinery development, and improved ginning methods.

The development of mechanization is dependent on research in each of these subjects. New advances in mechanization in one field, therefore, may raise questions that have to be answered by research in one or more related fields. Thus, today's scientists, farmers, ginners, and industrial processors know they must keep in close touch with each other if the problems of cotton mechanization are to be met as promptly and efficiently as necessary.

NEED FOR MECHANIZATION

Mechanization of cotton production to meet the need for greater efficiency was stimulated by three major conditions that developed at about the same time: (1) Mechanization of other farming operations, (2) competition in domestic and foreign markets, and (3) loss of farm labor.

Cotton farming in the past was a way of life. The large hand-labor requirements and the small acreages that could be cultivated and harvested by a farm family dictated in large measure the economic pattern of the agricultural South. Low production per man hour meant higher production costs and lower economic standards for farm workers. When other crops and farming operations began to be mechanized, this pattern still persisted in the South and the cotton farmer was at a competitive disadvantage in American agriculture.

Competition from other fibers, particularly synthetics, was becoming a formidable factor in the domestic textile market. Rayon provided the first real competition. It has been followed by an expanding number of other man-made fibers. Most of these fibers could be efficiently produced without hazards comparable with the uncertainties of farming. In world trade, competition from cotton grown abroad was increasing rapidly and foreign markets for American cotton were dwindling.

At the same time, farm labor supplies were shrinking. Agricultural workers were migrating to urban centers and industrial jobs. World War II drained away much of the remaining reserve supply and made the problem even more acute.

As early as 1930 it was apparent that these conditions confronting cotton must be overcome if the industry was to survive. The problem was not one of producing more cotton or less cotton, but to produce more efficiently. The solution is being sought through mechanization in an effort to reduce the cost of production.

REGIONAL DIFFERENCES

The development of methods and machines to streamline cotton production is complicated by the varied needs in separate regions of cotton cultivation. The four major regions of cotton production, grouped for discussion in this report according to similarity of practices affected by mechanization, are (1) the Southeast, (2) the Midsouth Alluvial Plains or Delta region, (3) the Southern High Rolling Plains, and (4) the irrigated Far West.

Some conditions under which cotton is produced overlap from region to region, and some different conditions exist in isolated areas outside these defined regions, such as the blacklands of Texas and other portions of Texas and Oklahoma where cotton is rain-grown with some irrigation.

Machinery and methods easily adapted in one region may be virtually useless in another. For this reason, in a discussion of mechanization it is necessary to recognize at least the fundamental characteristics of these regions.

The Southeast

The Southeast includes principally Alabama, Georgia, North Carolina, and South Carolina. Some cotton is produced under similar conditions in Kentucky, Tennessee, and Virginia.

Characteristics of the Region

More fertilizer is used here than in any other region. Several varieties of Upland cotton are widely grown in the Southeast. All have medium staple length and are similar in quality so that buyers consider they are getting definite characteristics when they buy Southeast cotton.

The crop is rain-grown. As a result, the water supply is erratic compared to controlled irrigation. The rain-belt cotton farmer cannot plan his season with any confidence that the crop will get water at the proper time. However, there has been some development in the use of irrigation in the region.

Sometimes the farmer's problem is one of draining water from the fields. In late summer there is normally a drought over most of the region, followed by fall rains. Characteristics are bred into plant types and cultural practices are adapted to fit this pattern so the crop will mature in the dry season and can be harvested before fall rains damage the cotton.

Percentage of Farms Producing Cotton

About 40 percent of the region's more than 2 million farmers produce cotton. In the major cotton-producing States within the region, this percentage is even higher. Southeast cotton farmers plant a little less than half the cotton acreage of this country and now produce about 30 percent of the country's cotton crop.

Problems in Mechanization

The region's biggest problem in mechanization is presented by the small acreages of cotton per farm. The farms are small and the cotton is frequently planted in several fields on a single farm. The average for the entire region is 14 acres per cotton-producing farm. Most farmers, however, plant less than 14 acres. At present, half the cotton producers in the region have less than 10 acres of cotton per farm. Nearly 90 percent harvest less than 25 acres, and 97 percent harvest less than 50 acres.

It is considered uneconomical to buy and use the largest power equipment on less than about 100 acres. Only 1 percent of the cotton producers in the region have 100 acres or more of cotton. Therefore, most machinery used in the area is medium to small in size. In some communities farmers with small acreages pool their resources to provide larger machinery. In others, even this is not practical because of the large number of very small farms in the same area on which the equipment would be needed at the same time.

Other problem areas in mechanization are created by weeds and grasses (particularly in early season), insects, and diseases. The region is heavily infested with boll weevil; and bollworms, aphids, and leaf worms are often major pests. Thrips, cutworms and other early-season insects frequently affect the stand, stunt the seedlings, and delay fruiting. Seedling diseases, too, are a serious detriment to getting a uniform stand, particularly because early rains and rapid changes in temperature encourage certain aspects of the seedling disease complex. Fusarium wilt, bacterial blight, anthracnose, and boll rot also cause damage.

Progress in Mechanization

The use of small machinery is increasing in the region as a whole. Normally, farmers in the Southeast buy power plow units first, then gradually add other equipment. The last operation to be mechanized usually is harvesting because of the difficulty in justifying the purchase and use of high-cost harvesting machines, and the lack of properly equipped gins for machine-harvested cotton.

During the past 15 to 20 years, the percentage of cotton land prepared with mechanical power has increased from 30 to 90 percent; the cotton planted with mechanical power has increased from 20 to 60 percent; the cotton cultivated with mechanical power has increased from 20 to 80 percent; and the cotton mechanically harvested increased from 0 to less than 2 percent.

The Midsouth

The Midsouth region includes Arkansas, Louisiana, and Mississippi. Most of the cotton production of the region is in the alluvial plains or

so-called Delta area, made up of bottom lands along the lower Mississippi River. The same characteristics can also apply to farms on alluvial soil along other rivers across the Cotton Belt. Cotton is produced in the upland areas of these States under conditions similar to those of the Southeast region.

Rainfall in the Delta is heavy, averaging about 50 inches a year; and the soils are deep, fertile, and level. The farms are large in comparison with those in the Southeast, and the largest machinery available can be used in the region. Medium staple varieties are generally grown, averaging 1 1/16 inches (plus or minus 1/32).

Problems in Mechanization

Most of the difficulties to be overcome in mechanization stem from the heavy rainfall and the warm, humid climate that promote rank growth. For instance, it is often necessary for a farmer to drain his fields so he can plant his crop at the proper time. Weed and grass control, defoliation, and crop residue disposal vary in importance according to seasonal rains. Weed control is usually difficult, and the cost of hand hoeing is higher in the Midsouth than in any other region. For this reason--plus the greater adaptability of current spray rigs to the larger production units--chemical weed control is being put to use more rapidly than in other regions. Farmers who do not face such a pressing problem are waiting for further developments in the chemicals and methods of treatment before using them. Also, erratic rainfall prevents definite planning for a crop year in the Midsouth, just as in other sections of the rain belt. The weed control problem varies directly with the amount of rainfall, so the amount of hand labor needed for the season is hard to predict.

Soil and water management is being recognized as the clue to high sustained production so important to mechanization. The use of anhydrous ammonia has made low cost fertility management possible. The judicious use of soil management practices to increase water intake and storage have reduced drought damage, and the use of irrigation as a standard production practice is in sight.

The boll weevil is the number one insect enemy in the Delta area. Bollworms, leafworms, and aphids are often major pests. With the change in cropping system furnishing preferred hosts to other insects, such pests as cutworms, army worms, thrips, lygus bugs, and spider mites are becoming more important.

Losses from diseases in this area result from seedling diseases (pre- and post-emergence damping-off and rhizoctonia sore shin); fusarium wilt; fusarium-nematode complex; verticillium wilt; bacterial blight, and occasional slight damage from leaf spotting organisms.

Progress in Mechanization

The conversion to machines in the Midsouth region has been more rapid than in the Southeast. Considering the region as a whole, the progress in mechanization has not been as rapid as in California, but some larger farms in the Delta were among the first in the United States to change over to complete cotton mechanization.

The number of mechanical pickers is steadily increasing and the practice of chemical defoliation is growing at about the same pace. Also,

such practices as cross-cultivation and flame-cultivation are especially well adapted to the area and are more widely used than in other cotton-producing sections. Chemicals have not entirely replaced hand labor in weed control, but they have helped to stabilize the hours of hand labor even in wet years.

The Southern High Rolling Plains

The Southern High Rolling Plains region is composed largely of the high plains of West Texas and areas having similar production characteristics in Central Texas, Western Oklahoma, and Eastern New Mexico.

Characteristics of the Region

Dominant soil types are fine, sandy, and moderately fertile. The land is generally smooth and sloping, and the altitude is high, ranging up to about 4,000 feet. The region is typically arid, with an average of about 20 inches or less of rainfall a year. The growing season is shorter than in any other region.

Only hardy, vigorous varieties are suited to the climate. Most of the types grown are short staple, 7/8 to 1 inch, and "storm proof" (the lint is held tightly in bolls that do not open fully with maturity) because of the frequent high winds and occasional heavy fall rains. Yields are uniformly low except on irrigated land where the harvest is about a bale to the acre.

Crops are generally grown on residual winter moisture plus the relatively light rainfall during the growing season. But irrigation has increased markedly during the last 15 years. By 1950 a total of 2,000,000 acres of farmland were irrigated in the Texas portion of the region. About the same amount of water is used each year on irrigated farms, but the timing of its use is varied according to the moisture needs of each particular season. There seems to be little difference in the degree of mechanization between irrigated and nonirrigated farms.

Progress in Mechanization

The region is particularly suited to mechanized production. The shift to machinery started early and has progressed rapidly. The early frost date and natural dryness in nonirrigated acreage allows freedom from complicating heavy foliage and weeds. It has been estimated that in this area one man and one tractor can grow and harvest 80 acres of cotton.

All cotton is either hand pulled or machine stripped after defoliation or frost. A survey among 324 cotton farms made in 1951 in the Texas High Plains showed 9 out of 10 harvested the crop at least partially by machine. Whether it is wise to use defoliants or desiccants before harvesting everywhere in the region has not been determined.

In this region, production practices are timed so that the crop is mature and harvested before fall rains cause the cotton to deteriorate in the field. Major disease losses come from seedling diseases and bacterial blight. Minor problems are caused by verticillium wilt, fusarium wilt, and Texas root rot. Insect losses are largely caused by bollworms, lygus bugs, cotton fleahoppers, aphids, thrips, cabbage loopers, leafworms, and spider mites.

The Irrigated Far West

The irrigated Far West is composed principally of land in the San Joaquin and Imperial valleys in California, parts of Arizona and New Mexico, and the Rio Grande area of Texas surrounding El Paso and Brownsville.

Characteristics of the Region

The soils are deep, fertile, and of high calcium content. Crops are grown under irrigation and, therefore, the water supply is regulated according to a definite plan. Chief varieties are from 1 1/16 to 1 1/8 inches in staple--about 95 percent is of the Acala group. California is limited by State law to Acala 4-42.

All the American-Egyptian cotton produced in the United States is grown in this region. This amounts to less than 40,000 acres of the extra-long staple crop.

The growing season is exceptionally long in most sections of the area. (Growing seasons are relatively short in the high altitudes of Arizona and New Mexico.) The fall is dry, enabling growers to harvest the crop and get it to the gin without weather damage. However, heavy fogs, starting in the late fall, cause considerable difficulty in harvesting.

Yields are very high, averaging from 650 to 700 pounds of lint per acre. Arizona averaged 1,039 pounds per acre in 1954 and about 1,000 pounds in 1955 to lead the nation in yields. About 8 percent of the country's cotton acreage is planted in this region, but nearly 17 percent of the total cotton crop is harvested here.

While the boll weevil, the number one insect enemy of the cotton crop, does not exist in this arid area, the bollworm, lygus bug, stink bug, fleahopper, and aphids frequently give trouble. In fact, during recent years, more pounds of insecticide per acre have been used by cotton growers in Arizona than in any other State.

Insects of lesser economic importance that often require attention in local sections of the area are: Saltmarsh caterpiller, cutworm, cabbage looper, thrips, leaf miner, cotton leaf perforator, whitefly, leaf roller, beet leafhopper, and the greenhouse leaf tier.

The seedling disease complex creates the most serious disease problem to cotton growers in the irrigated West, and there is some trouble with verticillium wilt and bacterial blight in localized areas.

Weed control has been a relatively minor problem in the area as a whole. But many farmers are troubled with Johnson grass and late season weeds. Hoe labor is most frequently used on early weeds and to control grasses that appear after the last irrigation. Research in chemical control gives promise of solving some of the acute problems with late season weeds.

Progress in Mechanization

Acreages are large. More than one-fourth of the cotton farms in California grow 100 acres and more. On these large acreages, cotton farmers are dependent upon mechanization to grow and harvest crops. Large equipment is generally used. It is possible to see more than 20 large

mechanical pickers in operation on one California cotton farm--all owned by one grower. Frequently the machinery is available on a custom basis (the grower rents the machinery or hires the job done). Only spindle picking harvesters are used except in experimental studies.

In some sections hand labor is still predominantly used for harvesting. This is true where labor is readily available and where extra long staple cotton is grown, for which picking spindles have not yet been adapted. In all sections, there is some hand picking for extra quality and also to harvest a first picking before the crop is mature.

Regional Approach

Against this background of regional differences, research on cotton mechanization is approached largely on a regional or State basis. Of course, some findings are adaptable to several States or regions. Close cooperation among research workers in various projects, therefore, plays an important part in the rapid application of research results to mechanization problems.

DEVELOPMENT OF MECHANICAL HARVESTING

The mechanization of cotton production was dependent upon the development of a mechanical harvester. First patents for a cotton harvesting machine were granted about the middle of the nineteenth century, but such problems as the uneven opening of the bolls and the leaves and trash deposited at the gin with mechanically harvested cotton were too complicated to be quickly solved. Research workers had a long way to go from the granting of first patents to the general use of mechanical harvesters in the cotton fields.

Stripping Machines

Strippers are simpler machines than pickers and were the first mechanical harvester to be put into practical use. (These machines strip the plant of its cotton, along with bolls, leaves, some small twigs and branches, and other debris.) This type of harvesting requires close correlation with special ginning equipment to handle the high percentage of foreign material in the seed cotton.

The practice of "sledding" cotton (stripping with a sled-like machine) was reported in the Texas Panhandle as early as 1914. Gradually other types of strippers were developed. These employed rollers, brushes, or finger-like mechanisms. Such strippers are widely used in the dry short-stalk areas of the Southern Plains, and in the Blacklands of Texas. By the middle 1940's strippers had almost entirely replaced sledding machines.

Strip-type harvesters have not proved satisfactory in humid areas of rank growth or in areas where plants develop shallow root systems. The new brush-type stripper and other experimental stripper roll materials show some promise in the in-between areas of medium-heavy growth.

The Spindle-Type Picker

Interrelated research to develop a practical cotton picker and compatible cultural practices was being carried out throughout the latter half

of the 19th and first half of the 20th centuries. After long years of experimenting and testing, the spindle-type cotton picker went into commercial production in 1941.

The spindle-type picker draws the cotton from open bolls and leaves unopened bolls for later picking, either by hand or by machine. It harvests much cleaner cotton than the stripper type but has not yet been as successfully used on a "once-through-the-field" basis. Various types of spindle pickers are in use in the Southeast, Delta, and the irrigated West.

The efficiency of harvesting machines has now been developed to the point that machine-picked cotton can match hand-picked cotton in grade when it is properly handled and when other cultural and ginning practices are properly related. Those who have studied the situation closely have put it this way: "When the farmer and the ginner both know what they are doing, machine-picked cotton can grade as high as hand picked." To maintain the grade ginners and farmers must be properly equipped and operating with full knowledge of the best methods developed by research.

However, most of the cotton crop is still harvested by hand labor. During the 1955-56 season, the approximately 18,000 spindle pickers and 23,000 strippers used by cotton farmers harvested between 20 and 25 percent of the crop. About 54 percent was hand-picked and about 23 percent hand-snapped.

CONTRIBUTION OF PLANT BREEDING

The influence of the mechanical harvester is felt as far back in the process of cotton production as plant breeding research. Not all adaptations are being made after the crop is in the field. The very nature of the cotton plant is being changed to fit the needs. It is usually easier to change a machine than it is to change the plant through breeding, but the plant breeder was asked for a cotton plant that would lend itself better to spindle picking.

Ideal Plant for Spindle Picking

Several characteristics would be combined in the perfect type of cotton for spindle picking, some of which are genetically antagonistic. For this reason, the ideal blend of characteristics is not in sight today, but marked progress is being made.

The goal in plant breeding research for more efficient mechanization is to combine in a plant as many as possible of the following characteristics:

(1) A strong central stem anchored by a well-developed root system.

(2) Early developing and maturing bolls.

(3) Bolls set evenly over the plant beginning high off the ground.

(4) Fluffy bolls for easy picking but, at the same time, lint held firmly enough in the bolls for good storm resistance.

(5) A minimum of small leaves that shed easily, from natural causes or as a result of chemical defoliation; glossy or non-hairy leaves which are easily removed from lint at the gin.

Strong Stem and Root System

The strong central stem and good root system only recently have been recognized as important to mechanical harvesting. These characteristics help to hold the plant upright and firmly in the ground during harvesting. Plant breeders are now alerted to the need, and selective breeding is being carried out with these qualities in mind.

Spacing of Bolls

For the mechanical picker to harvest as much cotton as possible from every plant, it is necessary to have the bolls well spaced and high off the ground. Early maturity is needed to enable the picker to harvest as much of the total production as possible on a once-through basis and to permit early harvest in areas where fall weather damage is a problem. To appreciate the problem of developing a plant with early maturing bolls, concentrated relatively high off the ground, it is necessary to understand the fundamental growth habits of cotton.

The cotton plant grows principally from the apex of its main stalk. At each node or joint of the stalk, a leaf develops. From the leaf, both a vegetative and a fruiting branch can develop. Only the fruiting branches produce blooms, which in turn produce bolls.

After the first bloom forms on the lowest fruiting branch, there is an interval of about 3 days before the first flower develops on the next higher fruiting branch. The vertical interval of blooming, then, is 3 days. But horizontally, on a single fruiting branch, the interval between blooms is about 6 days. That means that blooms appear every 3 days going up and every 6 days going out. It also means that the lower the first fruiting branch the earlier the start. Therefore, the concentration of bolls high on the plant is not normally associated with early maturity.

This poses a problem for plant breeders in attempting to develop a plant with both characteristics, particularly without reducing total yield. However, most of the Upland varieties developed in recent years are early maturing plants. With some of these as breeding stock, it is genetically possible to improve the combination of the two characteristics, and breeders are giving considerable attention to developing rapidly and early maturing bolls higher on the plant. Many of the newer varieties have a markedly higher yielding potential than those that had been previously produced.

Storm-Proof Plants

So far, storm-proof cotton has been associated almost entirely with machine-stripped cotton, but research is now attempting to develop bolls that are not highly susceptible to storm damage and yet adapted to spindle picking. Some success has been reported with certain varieties in Texas.

Smaller Leaves

The attempt to breed plant strains with small leaves that shed easily and are non-hairy is directed at reducing the trash in harvested cotton, and thus improving the quality. Breeders have also worked with a number of plant strains with small, narrow bracts (leaf-like parts at the base of the boll), some of which dry up and drop off by the time the boll matures. So far, these characteristics have not been successfully combined with high yielding varieties.

Plants Adapted for Mechanical Stripper

Cotton varieties particularly adapted to the mechanical stripper have been developed and are now available. The principal characteristics of these varieties are a storm-proof quality of the lint and a semi-cluster fruiting habit. However, plant breeders recognize that further improvements, such as higher fruiting, earlier maturity, and easier defoliation, would improve the efficiency of the stripping operation.

LAY OF THE LAND

In precision cotton farming, the grower finds his operations are changing even in the planning stage. He must consider field layout, drainage, and soil conservation in the light of mechanized production. Perhaps the size and shape of his cotton field was satisfactory for the mule and hoe, but when he adds a high-speed rubber-tired tractor he might have to move a fence, a road, or a turnrow. If his fields are not properly drained, a low spot might keep him from bringing in machinery for weed control, insect control, or even harvest when he needs it. Properly leveled and drained fields are necessary also to help insure uniform crop growth.

Studies have shown that field layout should be planned on the farm as a unit. Often the plan should encompass several farms or a whole community. The requirements for an individual field can then be fitted into the plan for the unit.

Contoured rows and terraces present a problem on land subject to erosion. However, experiments in South Carolina and Alabama have shown that cotton can be completely mechanized on relatively steep terraced and contoured land, if the conservation measures are carefully prepared and maintained.

CROP RESIDUE DISPOSAL IN MECHANIZED PRODUCTION

Although stalks and other residue of a crop are destroyed as the last operation of the crop year, the effectiveness of the disposal becomes an important consideration at the beginning of the season. Before a farmer can prepare a seedbed, he must be sure that the residue from the previous crop is covered or worked into the soil for decomposition. The necessity for effective disposal is even more acute in a mechanized operation because large stalks, roots, and stubble will make accurate, uniform planting extremely difficult. Furthermore, the residue will hinder weed control by clogging chemical applicator shoes, rotary hoes, and sweeps. Mechanical harvesters, especially strippers, are easily clogged by large pieces of stubble and roots.

The Blade-Type Cutter

Up until about 20 years ago, it was a common practice to cut, rake, and burn cotton-crop residue after the crop was harvested. Today, various types of machines are in use to reduce the labor required for the job. The most common tool in areas where stalks do not grow rank is the rolling blade-type cutter, followed by the disc harrow.

In the Delta and on heavily irrigated land of the West, the rank growth makes residue disposal a major problem. The blade-type cutter is not

effective. Through the cooperation of public and private research, the power shredder has been developed within the past 10 years to meet the problem in these areas, and it is now in common use.

The Power Shredder

More than a dozen makes of power shredders have been tested in the field and found to be efficient. However, it was also found that their life expectancy is low, the power requirements high, and the initial and operating costs are excessive. Agricultural engineers recognize the need to improve the machine and eliminate some of these drawbacks. Research is now developing new types of power shredders to remove roots as well as stalks and branches in order to dispose of all stubble that interferes with the operation of machinery.

In addition to their value in crop residue disposal, power shredders have proved to be of exceptional value in early stalk disposal which aids in controlling such damaging insects as pink bollworm. The shredder does an effective job of destroying the residue in which the insect survives, and also some of the insect population. In some areas where the pink bollworm is a serious problem, destruction of crop residue by a certain date is compulsory.

SEEDBED PREPARATION

Seedbed preparation practices vary considerably across the Cotton Belt and often within any one region. Some variations are necessary because of different soil types and climates. Others are little more than different customs built up over the years.

Mechanization has provided the plows and power to work soils to whatever extent may be necessary for a particular soil and climate. The type of equipment used and the number of times a seedbed must be worked depends upon how well the previous crop residue was disposed of, the type of soil, the rainfall, and the weed and grass conditions.

CHANGES IN PLANTING METHODS

In the past, a cotton farmer planted large quantities of fuzzy (gin run) seed and hand thinned to the desired stand. He generally used a slow moving drill-type planter. But these practices do not fit into a mechanized operation.

The first requirement was to devise a method that could be carried out with greater speed and less labor. It was necessary to get greater planting accuracy to insure a uniform stand and save seed.

Precision Planting

In answer to these needs engineers have developed precision planters. Seed can be accurately spaced in the soil, either by drilling or hilldropping. The development of the seed press wheel for pressing the seed into firm, moist seedbeds before it is covered with soil has been of considerable value. Methods of mechanical or acid delinting have been perfected to provide smooth seed for planting and thus further insure accuracy.

Spacing the Plants

Scientists have determined how to space, fertilize, and irrigate cotton for best yield and quality. They have studied the effect of spacing on growth and development to provide plants that are efficient for mechanical harvesting. For instance, if widely spaced, the vegetative limbs grow lower on the plant. But if crowded until plants are a foot or less apart the development of the plants is more efficient for mechanized production.

Crowding the plants tends to do three things:

(1) Decreases the number and length, or eliminates, vegetative branches, making the plants more compact.

(2) Increases the height above the ground of the first bolls.

(3) Increases the shading effect on grass and weeds in the drill row.

Planting to Stand

Research is making progress toward providing the knowledge of how to plant for efficient mechanized production and the precision machines for accurate "planting to stand" (planting the crop as the farmer expects it to grow and mature, without thinning). Complete mechanization depends heavily on planting to stand. Yet most cotton farmers in all regions are still planting thick and then thinning because they cannot be sure the crop will emerge and grow to a desired stand.

Seedling diseases and the use of improper planting equipment or methods may prevent some of the crop from emerging. Other diseases and insects may damage growing plants and cause the loss of early squares (the bracts and immature flower enclosed). Heavy rains and other adverse weather conditions early in the season may either prevent some of the plants from emerging or kill some of the young growing plants. As a result, every year many stands are lost completely, or only two-thirds or one-half a stand matures. These partial crops cannot be efficiently defoliated or machine picked.

This dependence of planting and harvesting methods upon such factors as the control of disease and insects demonstrates again the close relationship among the various aspects of mechanization. It emphasizes the need for approaching research on the problems of mechanization on an interrelated basis.

FERTILIZATION AND IRRIGATION

Methods of fertilization and irrigation influence mechanization principally as means of controlling the growth and maturity of the crop for efficient machine cultivation and harvesting.

When the crop is harvested by hand, many farmers keep cotton growing full-tilt until stopped by cold weather. Pickers might go over the field two or three times. The crop from the first picking is usually the highest grade and brings price premiums. Grade usually declines with subsequent pickings. The late, weak, immature, and often frost-damaged cotton is discarded or sold at greatly reduced prices.

With machine harvesting--although two pickings are frequently made in the rain belt--the crop is more efficiently harvested all at one time at the end of the season, particularly with machine stripping. If the continuing growth of the cotton plants has been encouraged, inferior and immature bolls are harvested along with the high quality cotton and sold in the same bale. The resulting lower grade reduces income.

Therefore, there is an increasing tendency to manage fertilizers and irrigation water, where necessary, so that the plant uses them up by the end of the growing season. This control helps to discourage the continuing growth of the plant and late development of inferior bolls. It is not adaptable in all regions, but the practice is spreading.

Under full irrigation the objective is to give the plant all the water it can profitably use while the weather is favorable, then cut it off so that the plant can mature its crop of bolls during the most advantageous part of the season. For instance, if it takes 45 days to mature bolls in midsummer, it may take 70 days to mature them during the season of cool nights in the early fall. Late maturity, therefore, is inefficient.

The plants should slow down vegetative growth when hot weather tapers off. Then, as the drain of boll maturity affects the plant, vegetative development will stop and no more new bolls will be stuck. If timing has been correct, the majority of the bolls should be mature and ready for harvest before regrowth begins. Also, such plants are in ideal condition for chemical defoliation because leaf fall is a function of maturity.

The value of irrigation is being studied in the rain-grown areas of the Midsouth and Southeast, and many questions are still to be answered.

INTERRELATED ASPECTS OF CULTIVATION

The principles of cultivation have not been changed with the coming of machines. Mechanization, however, has introduced new methods and practices such as rotary hoes and high-speed sweeps, cross plowing, flame cultivation, and the use of chemicals.

An important development in the mechanization of cultivation practices is the use and interdependence of agricultural chemicals. The application of a chemical for one purpose frequently influences the rate and time of application for another.

Until the appearance of organic insecticides, there was little or no interest in controlling insects that cause the stunting of the plant and the shedding of young squares. In fact, 20 years ago there was little attempt to control weevils until later in the season, when a relatively high percentage of the squares were already infested. The cost of earlier control was considered uneconomical.

When organic insecticides, herbicides, and defoliants all became available in liquid form, agricultural engineers had the incentive to develop tractor-mounted low pressure, low volume spray machines and multi-purpose spray rigs. With this equipment, early insect control became economically practical. Now scientists are trying to determine more exactly the net advantages of saving all the early fruiting potential. Furthermore, they are reviewing "earliness" potentials of varieties and cultural practices to see if further gains can be made in yield and better timing of crop development to fit into the mechanical pattern.

A poor job of weed control lowers yield, quality, and dollar return per acre. Removal by hand hoeing is a high cost item in crop production, averaging from $15 to $20 an acre annually in rain-grown cotton in 1955. When mechanized harvesting equipment is used, weeds lower picker efficiency and reduce the grade of lint.

Intensive investigations have been started to find materials, methods, or devices to replace the man with the hoe in the cotton field and to do a better job of weed control. Federal, State, and private research have been put to work on the job.

Promising developments have been made in the field of chemical herbicides, both pre-emergence (applied before the crop comes up) and post-emergence (applied after the crop emerges). In the portion of the rain-grown cotton areas where early season weeds are a critical problem, the use of herbicides is being adopted on an increasing basis. Additional research is required, both on materials and methods of application, before chemicals will be used broadly in other areas of the Cotton Belt.

Most annual weeds in rain-grown cotton can be controlled by pre-emergence spraying with CIPC [isopropyl N-(3-chlorophenyl)carbamate]. Two newer herbicides have shown promise--monuron [3-(p-chlorophenyl)-1, 1-dimethylurea], diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea].

Savings in costs of weeding in the relatively dry years of 1953 and 1954 ranged from about $2 to $10 per acre with the use of CIPC as a pre-emergence herbicide in rain-grown cotton. Little or no injury to cotton stand and yield was reported when CIPC was applied according to recommendations. Dosages varied according to climate and soil type, but generally 1 1/2 to 2 1/2 pounds per acre controlled most annual weeds for about 2 to 6 weeks.

The urea herbicides monuron and diuron are very effective in controlling weeds. However, they are extremely potent and require highly accurate application to avoid overdosage and resulting damage. Overdosage is not only hazardous to the cotton plant, but at higher rates the materials remain in the soil and may injure certain crops following cotton. Although they are very promising the urea herbicides are not recommended for general use on cotton because the importance of the residues in the soil is not clearly understood.

Certain other chemicals are under intensive study as pre-emergence herbicides for cotton, but information about them is limited. Much more should be learned about such characteristics as their reactions in different soils under varying weather conditions.

A limiting factor in the use of pre-emergence herbicides is the possibility of having to replant a crop. A farmer may have to replant large acreages of cotton one or more times because of adverse weather conditions. He may be able to justify the cost of applying pre-emergence herbicides once, but probably not twice or three times. In addition, he has wasted his original investment in the application.

But in the hot and humid areas, like the Delta, weeds must be controlled if cotton production is to be completely mechanized. Pre-emergence herbicides provide the best protection available during the first weeks

of the crop season when plants are delicate. Once the plant develops several true leaves, it changes into a rather hardy plant and is ready to withstand mechanical weeding. Therefore, growers in areas where weeds are a major problem are using pre-emergence chemical herbicides even in their present stage of development to help control weeds during the early critical period of the crop. Weeds in the middles and late season weeds are usually controlled by conventional methods.

Post-Emergence Herbicides

In complete mechanization post-emergence chemical treatments to control weeds are usually necessary. So far, the cost of application makes it uneconomical to treat the middles (area between rows). Weeds growing in the untreated middles should be controlled by cultivation without throwing fresh soil or clods into the treated area, not only because the soil introduces viable weed seeds, but also because it hinders effective post-emergence chemical treatment.

Special non-fortified herbicidal oils applied as directional sprays control annual weeds at low cost when used properly and at the right time. One to three applications usually control weeds that escape the pre-emergence treatments in the drill row.

High precision in applying herbicidal oils is necessary because the sprays must be directed below the cotton leaves (no higher than 1 inch above the soil) and in such a manner as to hit the young weeds in the drill row. Uniformity and smoothness of seedbeds and precision adjustment of mechanical spray equipment are prime prerequisites to proper oil treatments.

Although oils will control weeds in cotton, there are certain limitations to their wide usage, including the precision with which they must be applied, the exact timing of the application for effective results, and the lack of residual effect on ungerminated weed seed.

New materials now being studied show promise not only of controlling growing weeds in cotton, but also for preventing the germination of weed seeds in soil for 2 to 4 weeks after treatment. Spot treatments to young, rapidly-growing Johnson grass with the new herbicide, 2,2-dichloropropionic acid (dalapon) has shown promising results. Sufficient work has not yet been done to recommend any of these materials for general use.

Chemicals in Irrigated Cotton

Application of pre-emergence herbicides to irrigated cotton in the West have not been effective. Furrow irrigation techniques have so far defeated the use of such chemicals. Furthermore, in the absence of rainfall to carry the herbicides into the soil, weeds frequently escape injury from material applied to the surface. Efforts are being made to incorporate pre-emergence materials in the top soil layer by mechanical means, but results have been inconsistent. Considerable progress has been made in Arizona in applying monuron and diuron at "lay by" as a directional spray to control annual morning-glory and certain late season grasses.

Mechanical Control Methods

Several mechanical methods are used to replace or reduce hoe labor in controlling weeds. The "cut-and-cover" or just the "cover" method

of cultivation is the most common still used for weed control. "Cut-and-cover" is accomplished by the use of a disk or knife to cut the weeds and soil from near young cotton plants and cover the "cut" and grass at the base of the plant with soil thrown up by sweeps. The cover method is simply the use of sweeps to throw soil up under and around the plants in an effort to cover grass and weeds.

Among the less expensive and simpler methods of weed control is cross-plowing (plowing both down the rows and across to uproot weeds). It has shown promise in flat fields where soil erosion is not a problem. Use of the practice is increasing in the lower Mississippi Valley because it helps to reduce the cost of weed control and, hence, the cost of total crop production, by replacing at least a part of the more expensive hand hoeing and conventional cultivation. Best results in limited field plot experiments were obtained when cross-plowing followed either pre-emergence herbicidal treatments or post-emergence oil treatments. In this practice, cross-cultivation is used to control mid-season annual weeds and also perennials such as Johnson grass and nutgrass.

The disadvantages of cross-plowing are: (1) More seed is required per acre to obtain a thick stand so that the hill of plants remaining is short and compact after some of the plants are removed by the plowing, (2) erosion problems are often created, and (3) if pre-emergence herbicides or post-emergence oil treatments are not applied, annual weeds may infest the hills.

The use of flame cultivation to control weeds in cotton has had its "ups and downs." The round-type burners, first used about 10 years ago, were unsatisfactory. In about 1948, agricultural engineers conducting the State-Federal cooperative cotton mechanization project at Stoneville, Miss., developed a new type of burner which was fitted with a flat nozzle. A similar type, the Arkansas burner, was developed more recently. Extensive tests have been made using different burner settings and pressures. Considerable success has been achieved in both experimental and practical use in the Delta and in California.

The timely application of flame cultivation, used in combination with sweep cultivation, will keep weeds and grass under control in cotton after the plants are 6 to 8 inches tall, provided weeds are already under control at that stage of growth. The cost of the practice, above that of regular cultivation, is approximately 50 cents per acre per application. Four to 6 applications are usually sufficient.

Before 1952 late-season flame cultivation of rank cotton with a standard row-crop tractor had not proved satisfactory because of the low axle clearance of the tractor. Industry developed a high-clearance tractor (36-inch clearance) with shields and equipped with front- or rear-mounted burners. This machine can be used to flame cultivate cotton (ranging in height up to 4 feet) until the bolls begin to open. Flame cultivation has been effective, also, in controlling weeds and grass in irrigated cotton.

In general, the success of flame cultivation is directly dependent upon the ingenuity and ability of the farmer who is using it. It is not the complete answer to weed control in cotton, but many who use it consider it a useful aid--sometimes quite valuable.

Other recently developed mechanical methods include the rotary hoe and various weeder attachments which destroy weeds by breaking up the soil in and around the plants.

In the mechanized operation it is essential to grow cotton that is fast fruiting, early maturing, compact, and off the ground with as nearly uniform maturity as possible. Insect damage can play a large part in preventing achievement of this objective. A farmer can plant early varieties, closely spaced; he can fertilize and irrigate to produce sturdy, heavily loaded plants which stop both fruiting and vegetative growth early in the fall--all favoring early and uniform maturity. But poor insect control can result in the plants being more vegetative, more indeterminate--can result in their being hard to defoliate and difficult to harvest because of scarcity of bolls and poor boll distribution on plants that are too big.

Insect control is important, too, in the effort to make cotton production more efficient. It has been estimated that 10 years ago cotton insects destroyed 1 in every 7 bales of cotton produced. The loss estimate is still 1 bale in 7.

This apparent lack of progress is not due to a lack of successful research and application of its findings. It is partly a reflection of more knowledge of insects and more accurate reporting of the damage they do. As a result, cotton damage estimates have been revised upward more nearly in line with actual losses caused by insects. Also cotton plants have been improved--they are more attractive to insects that in turn develop larger and more destructive populations which are more difficult to control.

Actually, methods of insect control have improved as rapidly as other phases of mechanized production. Insecticidal dusts have been applied to cotton since calcium arsenate was developed more than 30 years ago to control the boll weevil. Hand-operated or horse-drawn machines were used until tractor power came to the farm and dusting machines were developed to operate from the power take-off on tractors. In recent years aircraft have been widely used to dust or spray large acreages rapidly.

Development of Sprays for Use on Cotton

The use of spray applications was slow in developing, and available insecticides that could be sprayed were ineffective in the control of the boll weevil. The development of the chlorinated hydrocarbon insecticides in the middle 1940's helped to cross this barrier, and the search was intensified for spraying equipment to make their use practical. The increasing use of other agricultural chemicals in the cotton fields helped to speed the engineering research. Methods of applying the chemicals using both tractor-powered and aircraft equipment have been developed and insecticide sprays are becoming widely used.

Spray applications have an advantage over dusts because they can be used throughout the day and under more adverse weather conditions, especially with ground equipment; and they fit more easily into the farmer's daily work schedule. Dusts are usually applied only during the night, early morning, or late afternoon when weather conditions are more likely to be favorable.

Early Season Control

Early season insect control has gained more attention as mechanization progresses. The practice helps to insure earlier and more uniform maturity of the crop. The development of new machinery has made it

possible to combine early season insect control with early cultivation, using the same power equipment at the same time. This combined operation reduces costs and saves time and labor for the grower.

Destruction of Crop Residue as Insect Control Measure

The use of stalk cutters and shredders has been a great help in insect control. Early destruction of cotton stalks was one of the first recommendations by entomologists for cultural control of the boll weevil. This destroys the food supply, stops late-season breeding, and causes adult weevils to enter hibernation in a weakened condition, thus increasing winter mortality. When carried out on a community or county-wide basis the practice has greatly reduced the boll weevil problem. This is especially true in several areas of southern Texas where stalk destruction is mandatory by certain dates, beginning August 31 in the Lower Rio Grande Valley, for destruction of boll weevil and pink bollworm.

Early destruction of crop residue is considered one of the best weapons now available in the battle against the pink bollworm. Tests have shown that power shredders have killed as many as 70 percent of the pink bollworm larvae remaining in bolls on standing stalks. Research workers are hopeful that future improvements in machinery will make it possible to kill 100 percent.

The Machine Stripper in Insect Control

Furthermore, the use of the machine stripper is of great value in the control of pink bollworm. All bolls are removed from the field in this method of harvest. In hand picking, the green bolls, unpickable bolls, and some open bolls are left on the plants. In affected areas this material is often heavily infested with pick bollworm larvae, which are left in the field to threaten next season's crop.

With machine stripping, the source of pink bollworm infestation may be shifted to the turn row or other parts of the farm and to the gin. In the better type of strippers, green bolls that cannot be ginned are separated from the open bolls and are usually dumped on the turn rows or elsewhere on the farm before the cotton is hauled to the gin. This material should be burned, composted, or treated in some effective manner to eliminate the hazard on the farm.

Pink Bollworm Control at the Gin

Cooperative research between Agricultural Research Service engineers and entomologists has developed a method of destroying all pink bollworms in handling waste material from gins and cotton seed oil mills. The waste material is treated with the aid of fans. Further research results have shown that modern gin methods kill much more of the pink bollworm population that comes to the gin in seed cotton than was previously believed. This finding, coupled with the fan method of treating waste to remove the few insect pests that remain after ginning, make it possible for the farmer to haul gin waste back to the farm for soil building without expensive fumigation, thus saving the cotton industry about $2.5 million a year.

Defoliation and Desiccation as Insect Controls

Chemical defoliation and desiccation--necessary to mechanical harvesting in many areas--also aid in the control of cotton insects. The

growth of the plants is usually checked and the opening of mature bolls accelerated. This reduces immediate insect damage and late season build-up in pink bollworm and boll weevil populations, thereby helping to reduce the carryover of these insects. It also prevents or reduces damage to open cotton by heavy aphid, whitefly, and cotton leafworm infestations. Early defoliation permits an earlier harvest and better use of mechanical pickers, which in turn permits earlier stalk destruction.

Development of New Control Measures

The development of the new organic insecticides now in use for cotton insect control and the mechanical equipment for their application have helped considerably in making cotton production more economical. Furthermore, current research on the new systemic insecticides is opening new vistas in cotton insect control. (Systemic insecticides move through the plant with the sap, killing insects that bite the plant or suck the sap.) Some of the systemics tested as seed treatments have given outstanding results in certain areas. Before they can be generally recommended, safer and more effective insecticides and better means of applying them must be devised.

Insect Control with Irrigation in Rain-Grown Cotton

The trend developing toward the use of irrigation in normally rain-grown areas creates a new problem in insect control. On these spots of irrigated land, plants continue to fruit after cotton on surrounding acreage has matured and stopped growing in the seasonal drought. These areas of green, growing plants attract late season insects. So far, the only answer has been costly, intensified chemical control treatments.

DISEASE CONTROL

Cotton diseases comprise another of the interrelated aspects of mechanized cultivation. Diseases which contribute to spotty stand or uneven maturity, and even cause replanting, interfere with mechanical efficiency.

Cotton has never been subject to serious epidemic diseases such as those that attack small grains. Yet, the losses suffered each year from disease, according to present estimates, equal about one-seventh of the country's crop. If these losses could be reduced or prevented it would mean a considerable reduction in the per unit cost of production.

Seedling Disease

The most serious problem in all areas of production is that of the seedling disease complex which prevents normal germination of seed and growth of the plant. It is frequently the cause of replanting and other crop deficiencies. Effective treatments have been developed to prevent many seedling diseases, and proper seed treatment is considered the best assurance of getting a uniform stand from the first planting. But only about two-thirds of the planting seed is treated each year, and seedling diseases rank as the No. 1 cause of disease loss in cotton.

The Problem of New Diseases

Many of the diseases of cotton that have been studied for a number of years can now be controlled by the use of resistant varieties, fumigants,

cultural practices, or fungicides. On the other hand, diseases that have been recognized only recently are becoming increasingly widespread with no effective means of control. For example, verticillium wilt, asochyta blight, and rhizoctonia soreshin already rank among the more destructive diseases. No varieties of cotton have been developed that are fully resistant to them, although promising strains showing some tolerance to verticillium wilt have been developed. Application of certain fungicides in the furrow at planting time has been shown to reduce the damage from rhizoctonia soreshin, but the research results do not yet point to definite recommendations.

TOPPING

In areas where cotton grows tall and rank, topping is sometimes necessary to make sure the crop is in proper condition for machine harvest. The tall, heavy plants sometimes lodge (fall over) so the crop is difficult to harvest. Defoliation is also difficult and boll rot frequently develops on the lower part of the plants. If these problems are encountered, growers sometimes combat them by topping or cutting off the terminal bud of the main stalk to prevent excessive growth. Experiments are being conducted to find the best time and height for topping. Results so far indicate plants should be topped at about 4 feet when they are between 4 and 5 feet high.

Topping usually has been carried out by hand. Tests conducted in California since 1951, however, have shown that machine topping can be effectively used to prevent lodging without reducing yield. Several types of satisfactory machines have been developed.

DEFOLIATION AND DESICCATION

Cotton is a perennial plant and sheds its leaves naturally when they mature. That is normal defoliation. The process can be brought on by drought, disease, plant food deficiency, or light frost. It can also be speeded up and timed to meet the requirements of mechanical harvesting by the use of chemical defoliants.

Requirements for Spindle Picking

Chemical defoliation and the spindle picking machine were natural companions in research development. Actually, defoliation was first investigated as a method of controlling boll rot by letting more sunlight through to the lower bolls. But when the spindle picker was introduced in the 1940's, defoliation became a necessity in cotton that was rank, leafy, and succulent. The picker left too much cotton in the fields. Furthermore, at that time few gins--outside the stripper harvest area of the Plains--were equipped to remove excess trash or dry out the stained wet lint or green leaves that might be harvested with the cotton.

Since then machines have been improved so much they can now do a better job in leafy cotton. Operators have had enough training and experience to handle the machines more efficiently. The improvements in cleaning and drying equipment at the gins have been remarkable.

Thus, today, the need for defoliation in relation to machine picking efficiency is considerably diminished. It is still needed and probably will continue to be a factor in spindle picking efficiency where there is an excess

of moist foliage, a full boll load, and a tendency for plants to lodge or tangle or for the bolls to rot.

Requirements for Mechanical Stripping

The mechanical stripper sets up a different need. The job must be done all at one time, and if green leaves are harvested with the lint and dry burs, it presents a complicated problem at the gin. Before defoliation came into practice, stripped cotton was sometimes piled in the field until it dried. The common early practice, however, was to wait until frost killed or dried the leaves before harvesting. This, of course, made harvesting late and cotton often deteriorated in the field before harvest.

The use of defoliants and desiccants now permits stripper harvesting within a week or two after the last bolls are open. In the semi-arid plains area, removal of leaves with defoliant chemicals has been found difficult. This has caused a swing toward the use of desiccants (herbicide-type chemicals which kill and dry out the foliage and other plant parts rather than cause the leaves to shed).

Varying Methods of Application

Variations in climate and growing conditions make it necessary to vary the defoliant and desiccant material used as well as the rate and time of application. Satisfactory dusts and liquid sprays have been developed along with machinery to apply them. However, ground spraying machinery is not entirely satisfactory in rank cotton. To get good results with liquid defoliants, it is necessary that the liquid come in contact with each leaf on the plant. This requirement plus the probability of mechanical damage to the crop makes the use of airplane spraying or dusting preferable in most areas of rank growth.

Timing the Application

The most critical single factor to be considered in defoliation is the timing of the application. If a defoliant is applied too early it causes reduction in yield that might offset any gain in grade or any advantage to machine picking efficiency.

To time defoliation properly a grower must know the cultural history and the exact physical condition of the plants, the relative maturity of the crop, the characteristics of the chemical defoliants, and weather conditions and weather forecasts. On the basis of this information, he might properly decide that he has nothing to gain by defoliation--even that he might reduce his income materially if he did defoliate. Or he might find that by applying a defoliant he could gain through improvment in the grade of the harvested cotton, better late insect control, less boll rot, and earlier and more efficient harvesting. It may even be an inducement to hand picking when hired hands prefer to pick in defoliated fields.

PROBLEMS OF SECOND GROWTH

Because cotton is a perennial plant, once its crop is mature it is ready to start a new cycle of growth and reproduction if nutrients, moisture, and temperature are favorable. In trying to harvest the crop early for an efficient mechanized program, farmers often defoliate so early that there is still some growing weather left in the season. Removal of leaves when

the crop is mature allows all the plant's facilities to be expended in new vegetative growth.

Regrowth quickly becomes succulent, lint-staining foliage, interfering with the use of mechanical harvesters. It also offers good feeding and breeding places for late season insects and provides an excellent environment for seed and fiber deterioration. Some farmers consider regrowth today's worst mechanical harvesting problem.

A new chemical was developed in 1954 that offers the first effective means of holding back regrowth long enough to permit complete machine harvesting. This chemical, called aminotriazole, was available by 1955 on a limited commercial basis. So far it is costly to use. However, studies have shown that it can be applied in combination with reduced rates of almost any other efficient defoliant to provide a two-fold result of defoliation and second growth control at a cost only a little higher than that for full strength application of the defoliant alone.

ADAPTATIONS IN GINNING METHODS

Ginning is the final operation in getting cotton in marketable condition. It is a very important factor governing the quality of the product and the income the farmer gets from his year's work. The lint remains the farmer's property until the crop is sold after ginning, and the market price is established on the basis of the grade of the cotton at that time. Unless the quality of the cotton is maintained through ginning the benefits of research in plant science and farm mechanization are largely nullified.

Ginning Defined

Ginning consists of drying or conditioning, preliminary cleaning to remove foreign matter, separating the lint from the seed, lint cleaning, packing the lint into bales, and recovering the seed. With clean, hand-picked cotton these are relatively simple operations. In fact, in the early days of ginning, no effort was made to dry or clean the cotton, and most growers ginned their cotton on their own farms.

Gradually, however, the introduction of hand snapping and other rough-harvesting methods complicated ginning problems and created a need for drying and cleaning processes. By the early 1900's several types of cleaning machines were on the market. Many individual farmers could no longer afford to buy the more expensive equipment, and commercial gins came into existence.

Problems with Machine Picked Cotton

With the widespread appearance of mechanical harvesters and other mechanized production practices, cotton began requiring an increasing amount of preliminary preparation at the gin. At the same time, considering the Cotton Belt as a whole, there has been a trend toward longer staple finer-fibered cottons which are difficult to clean without damage to the fiber. Hence, research workers, ginners, and ginning machinery manufacturers have been hard pressed to keep abreast of changing production practices on the farm that require new equipment and techniques at the gin to maintain the quality of the product.

Seed cotton brought to gins has an increasing amount of foreign material, some of which has a moisture content higher than that of the cotton. Moreover, mechanical cotton pickers use water for wetting the picking spindles to increase picking efficiency. But bulk seed cotton is easier to clean without damage when it is dry. Therefore, since the advent of mechanical harvesting, drying has become a more important part of the ginning process.

Progress in Solving the Problems

Patents covering both the drying process and the method of drying were obtained by the U.S. Department of Agriculture in 1928, and in 1931 the Department's Cotton Ginning Research Laboratory at Stoneville, Miss., successfully demonstrated the practicability of a seed cotton drier.

Commercial seed cotton cleaning machinery normally does a good job of removing burrs and other such foreign material but leaves small bits of trash such as leaf fragments with the lint. This foreign material reduces the market price of the cotton. Work was started by the Cotton Ginning Research Laboratory at Stoneville in 1938 to find a practical method of cleaning lint cotton at the gin. The development there of a cleaning machine located between the gin stand and the press started a series of improvements which probably will equal the value of the seed cotton drier. Industry has developed other types of such machines, and lint cleaners have contributed much toward making mechanical harvesting practical.

In some areas, particularly in the West and Southwest, gins are located long distances from compresses and cotton mills, and domestic shipping costs become a more important item. The standard density press has enabled gins to press cotton to a density of 20 to 30 pounds per cubic foot instead of the customary 10 to 12 pounds, thus saving storage space and reducing domestic shipping costs. Most gins in the western areas already have or are in the process of getting standard density presses.

Machine-stripped cotton is sometimes dumped on the ground before it is hauled to the gin. As a result it contains not only immature bolls and trash but stones and metal objects such as nails and other kinds of tramp iron. This causes unnecessary wear and tear and frequently breaks down cleaning and ginning machinery.

To combat the problem, a box-like trap was devised to remove green bolls and other heavy objects. This also allows for the more effective use of an electro-magnet to remove lighter pieces of tramp iron.

The elaborate drying and seed cotton cleaning equipment necessary for the conditioning and cleaning of roughly harvested cotton created a need to control the rate of flow of the cotton through the equipment. Erratic flow causes costly chokage, large overflows which are a fire hazard, and less effective operation of drying and cleaning machinery.

A bulk seed cotton feed control device has been developed and is available from ginning machinery manufacturers. This device increases the efficiency of driers, cleaning machinery, and the gin stand, especially for machine harvested cotton with large quantities of foreign material and a high moisture content.

Ginners have always had trouble with sticks in machine stripped cotton. Limb segments and sometimes whole limbs or plants are gathered by the harvesting machine and get into the ginning system and the gin stand roll boxes, thus substantially reducing gin capacity. In addition, bark and chips from these limbs become tangled in the lint, resulting in lower grades and prices. The larger segments damage the machinery, and those that get into the seed line reduce the market price of the seed.

A stick remover has been developed recently that does a good job of removing sticks and other foreign material. It is relatively simple and may possibly replace some of the more costly overhead cleaning machinery. It is now being adapted for use by the industry.

Other developments of the U.S. Ginning Laboratory which contribute to the handling and cleaning of mechanically harvested cotton include the following: (1) Revised moting system for gin stands which improves their cleaning efficiency; (2) improved saw tooth designs and greater saw speeds to increase gin capacity and give better separation of the lint and seed; (3) standardized sequence of seed cotton cleaning and extracting equipment to obtain best efficiency from a cleaning standpoint, and the determination of the amounts of this equipment which could be profitably used without fiber degradation; (4) introduction of grid type cleaning for the removal of small leaf trash; (5) improved seed handling; and (6) improved trash handling and disposal systems.

EVALUATING THE EFFECT OF MECHANIZATION

These, then, are some of the trends in cotton production from planting to ginning. But what effect have these trends had on the objective to increase efficiency of production?

One way to measure progress in more efficient production is to evaluate the yield and the volume of cotton production per man hour of labor.

Effects on Yield and Man Hours of Labor

During the 1928-32 period, an average of 41.4 million acres of cropland were planted to cotton each year. This land produced an average of 14.7 million bales. During the 1950-54 period, an average of 14.1 million bales of cotton were produced each year from an average of 23.5 million acres. This represents an increase in yield of 113 pounds of lint per acre--nearly 70 percent increase in the last 25 years.

Essentially the same amount of cotton was produced with less than one-half the number of hours of man labor. During the 1928-32 period it took an estimated 260 hours of man labor to produce a bale of cotton. In 1951-53 it took 115 hours per bale. The saving in man labor in producing the nation's annual cotton crop is equal to about 1 million people working a whole year--52 forty-hour weeks.

However, the release of 18 million acres of land for other agricultural use and the saving of over 2 billion hours of man labor every year is not all net gain. Some other materials and services which represent costs to farmers have been substituted for land and labor. Increased use of fertilizer, better weed and insect control, defoliation, and machinery itself are just a few of his extra costs.

When savings are balanced against added costs, it is plain that the introduction of the new techniques have reduced substantially the total cost of producing cotton. For example, it has been estimated that with mechanization as complete as possible today, cotton can be produced for about 10 cents per pound less than with mule and hand labor. Not only are unit costs lowered through mechanization, but a worker or farm family can handle a much larger acreage, thus increasing production and income per worker. This puts cotton in a better competitive position with other crops in the selection of land use on the individual farm. In addition, a more efficiently produced product is in a better competitive position with synthetic and other fibers in the market.

Factors Creating the Changes

Increased yields and lower labor requirements have been made possible in part by improvements in machinery and equipment. These as well as the other improvements in methods and practices are the result of research--research in many lines that tie together to bring about more efficient production.

It is not possible to say that any specific practice or technique is responsible for any definite amount of yield increase. All are closely interrelated and complementary in effect. Some of the causes are part of mechanization; others are merely indirectly related. Among the more important reasons for increased yields, not listed in any order of importance, are:

(1) The shifting of cotton, within and between regions, from lower to higher yielding acreages.

(2) The selection of better land for cotton on individual cotton farms.

(3) The increased use of fertilizer.

(4) Better irrigation methods.

(5) More effective insect, disease, and weed control over a wider area.

(6) Improved seed.

(7) Better cultural practices.

(8) Better timing and integration of production practices.

(9) Improved system of crop rotation.

Increased yields are partly responsible for the big saving in man labor requirements. It takes little or no more labor with proper equipment to get a high yielding acre up to harvest than it does a low yielding acre. The shift in cotton acreage toward areas requiring less weed control has some effect. But among the big factors is the improved power machinery of mechanization.

During the 1928-32 period about 150 man hours per bale were required in preharvest operations, compared with about 52 hours in recent years. That is a saving in preharvest work time of about 100 hours a bale. About 25 hours of saving was due to mechanized equipment and the remainder to increased yields.

Labor requirements for harvesting the total U.S. crop averaged about 115 hours per bale during the 1928-32 period, compared with about 65

hours per bale during the 1951-53 period--a reduction of 50 hours per bale. Some of this reduction is due to a shift from hand picking to hand snapping, but most of it is due to mechanical harvesting, which requires only 1 to 3 hours per bale.

In short, technological advances, which are the results of both public and private research, have increased the production of cotton lint from 1.9 pounds per man hour to nearly 4.2 pounds during the last 20 to 25 years. Thus, productivity of man labor has been more than doubled.

Effect on Cotton Quality

In this process of streamlining production, what has happened to the quality of lint? Research is always aimed at improving the quality of the end product through plant breeding and improved methods of cultivation and handling. But during the process of mechanizing production methods, there is a constant problem of maintaining quality that might be lost through the use of machinery. For instance, mechanical harvesting usually tends to lower quality by: (1) mixing top and bottom quality cotton in one bale, and (2) increasing trash in harvested cotton, which means more treatment at the gin. On the other hand, quality may be improved through mechanized production by getting the crop out of the field earlier, before it is subjected to late season weather damage.

Actually--as a measure of quality--average length of fiber has increased more than 1/16 of an inch, and average grade index has dropped about 2/3 of a grade. On the basis of present premiums and discounts, one about offsets the other. However, the extremely low grades make up a much smaller proportion of the total crop now than they did 25 years ago.

Shift in Major Cotton Production Areas

As major cotton production shifts toward those areas and farms best adapted to mechanization, a definite trend is beginning to show up. In such areas as the irrigated West, the Midsouth, the Southern High Rolling Plains and the Lower Rio Grande Valley, the production of cotton has increased materially. Mechanization has progressed rapidly in these areas and, except for the Southern High Rolling Plains, yields are considerably above the average for the country as a whole. Production has decreased considerably in such areas as the Piedmont, the Sandy Coastal Plains, and the Blackland area of Texas. Production has decreased moderately--about 15 to 30 percent--in such areas as the eastern Coastal Plains, and the Low Rolling Plains of Texas and Oklahoma.

RESEARCH NEEDS FOR THE FUTURE

Progress in cotton mechanization has indeed been impressive. But certain problem areas remain to be faced. Research will have to find more answers and growers will have to put those answers to work before cotton mechanization can approach completion.

The Problem of Small Cotton Farms

One of the big unanswered questions is what to do about small cotton farms, wherever they may exist. Harvesting and such practices as insect control and chemical weed control are handicapped by the lack of suitable small equipment. Many important insect control measures are now carried

out by hand or--more frequently--omitted. A greater variety of small, efficient machines needs to be developed if these farms are to compete in the era of mechanized production. Without such equipment, the future of the small cotton farm is uncertain at best.

Some of the producers on small farms where the new techniques and machines are not practical will need to consider adjustments in their systems of farming. Consolidation might provide answers for some small farms. Others will need to give less emphasis to cotton and more attention to other types of farming. The gradual shift of cotton production to those farms and areas better suited to mechanization is further evidence that the trend has started.

Meeting Market Demands

Related to the problem of changing patterns of production is that of producing to fit the demands of domestic and world markets. More cotton is being produced now than markets can absorb. The very fact that controls are now in effect to limit production of cotton means that additional acres are being taken out of cotton production.

Systems of farming should be better adjusted, not only to counterbalance the changes brought about by mechanization, but also the changes made necessary by the economic problems of production and demand, as well as other forces and factors of the domestic and world economy. Research programs should include a study of these economic and production problems.

Planting to Stand

A second problem area is the slow spread of the practice of planting to stand. The fact that most farmers are still planting thick and hand thinning is caused by several contributing factors that indicate the direction of further research in both methods and machinery. Research in machinery is just beginning to point the way toward developing special equipment suited for different field situations, including various soil types and weather conditions, that will enable farmers to plant to stand without risking the expense of replanting. The manufacturing changes necessary to provide this new equipment, the replacement of machinery now in use, and the training necessary for proper handling will take time.

Improved methods of soil and water management would also smooth the way toward planting to stand.

One of the biggest problems is the seedling disease complex. There is not yet available the ideal combination of seedling vigor (resistance to cold injury in particular), disease resistance, and chemical protection from disease to assure a farmer that the exact crop he plants will come up and grow. Therefore, research needs to develop better cold tolerance in seedlings (the capacity of seedlings to grow more rapidly at low soil temperatures), more seedling disease resistance, and better fungicides.

It is important to find how much cold weather present varieties will stand, and to make better use of existing weather facts and forecasts so the farmer can increase his odds against cold weather damage.

Weed Control

Better weed control is needed throughout most of the rainbelt to make it more practical to plant to stand, to increase the efficiency of machines in the field, and to improve the quality of the harvested cotton.

Improved equipment, adapted to different field conditions, is needed for mechanical, flame, and chemical weed control, or an effective combination of these methods.

Chemical herbicides have shown great promise and may well provide spectacular aid in weed control. The widespread, general use of chemicals will not be possible until further developments are made. Chemical herbicides will come of age when these requirements are met: (1) When they can be safely and effectively used despite changes in weather or climate, (2) when their use requires less precision, (3) when safer and cheaper chemicals are developed, and (4) when equipment and simpler techniques for application are developed that can be used effectively and efficiently by farmers.

Insect Control

Additional research in various fields of insect control is necessary if we are to continue to hold our own in the battle against pest damage in cotton. No insect pest has yet been totally eradicated from the cotton fields of this country, and new ones are being discovered nearly every year. Furthermore, several important insects, including the boll weevil, are apparently becoming resistant to the commonly used chlorinated hydrocarbon insecticides.

The development of more effective and safer systemic insecticides and methods of applying them could increase the practice of planting to stand. The proper use of soil insecticides against certain soil-infesting insect pests could also help to achieve that goal. New granular formulations may provide part of the answer. But the continuing development of new insecticides with different modes of action, new methods of application, or the discovery and development of entirely new approaches to insect control are essential if we are to continue to make progress.

Equipment for the most effective application of chemicals for insect control requires both basic and applied research. Each combination of insects, crops, chemicals, seasons, air movement, temperature, humidity, and equipment (aerial, ground, sub-surface) presents a different problem. Continual developments and changes in many of these variables require engineering research to compliment the research programs being conducted in these areas by entomologists and plant and soil scientists. Improvements need to be made in equipment from the standpoint of (1) control of points of application, (2) control of drift, (3) initial and maintenance cost, and (4) labor requirements. In some cases, the problem of excessive residues may well be improved by more accurately controlled and more uniform application.

More accurately directed and uniform applications of chemicals through improved equipment might well reduce the amounts needed for given applications by 5 to 10 percent, resulting in an estimated cost reduction to farmers of $20 to $40 million annually.

Regrowth Control

Better regrowth control across the rainbelt and in the dryland areas of Oklahoma and Texas would help to make mechanized production more efficient. Defoliants and desiccants now in use offer only a partial solution. Aminotriazole will do the job in many situations, but chemicals which are more permanently effective will be required to answer the problem for the entire belt. Research workers are even now trying combination treat-

ments for defoliation and second growth control with the aim of reducing application costs where both are needed.

Irrigation

The value of irrigation in the rainbelt should be more intensively investigated. Calculations of the frequencies and intensities of droughts from climatological information available reveal a definite probability of yield-limiting annual droughts even in the so-called humid sections of the country. This information indicates a need for irrigation as a standard production practice. Irrigation, however, is an expensive practice and should not be considered until other less expensive items of production, such as proper fertilization and stands, are carried out.

The proper use of added water must be learned by research teams of physiologists, soil physicists, chemists, and economists. Accepted rainbelt varieties may need new genes to take advantage of water when the plant can use it. Equally important, agricultural meteorology must be used much more widely than it is today if the grower is to be prevented from running his pumps 1 or 2 days ahead of a "gully washer." Studies on these problems are being conducted in the Southeast with the aid of long-time weather records, information on soil types, and the neutron counter to detect moisture content of the soil at a given time.

In deciding if irrigation is necessary and economically advisable in any instance, it is important to know precisely how much damage has been done to the crops by drought, how many more days without rain would be disastrous, and other related answers. Developing methods of getting the full information necessary, preparing adequate guides, and then educating growers will keep research teams busy for some time.

Control of Setting of Bolls

The ability to control the setting of the cotton bolls would be of great benefit. Normally cotton will set and mature not over one-half its total bloom production during a season. The control would come in making the cotton plant, through breeding and culture, set this 50 percent of the bloom at a time most advantageous to yield, quality, mechanical practices, disease and insect control, as well as to making the most economical use of fertilizers and water supply. More work is also needed on the influence of determinate varieties to control maturation.

Seedbed Preparation

Studies of seedbed preparation have been made to determine the best methods for each area. However, the need for more research is recognized to develop the best tillage and seedbed preparation methods and equipment for doing the job in the various soil types and different growing areas to aid in weed control, soil and water conservation, and increased yields.

Disease Control

Major objectives in the effort to improve disease control--in addition to finding better ways to combat the seedling disease complex--are to develop better chemical treatments, proper equipment for their application, and more resistance in cotton plant types. It is extremely difficult to treat properly the soil around and above the seed with the present type planting equipment. It is important, also, to make sure that cotton growers

recognize the need to carry out a continuous disease control program, beginning with the planting of treated seed.

Defoliants and Desiccants

Many questions are still unanswered about the use of defoliants and desiccants and about the chemicals themselves. Research workers must clarify the biological process of chemically induced leaf fall in plants before highly significant improvements can be made in defoliants.

Mechanical Harvesting

There is considerable need for research leading toward adapting harvesting machinery to smaller farms. Mechanical harvesting at the present stage of development is applicable primarily to the larger farms. Research is also needed for adapting harvesting machinery that possesses greater picking efficiency, maintains quality of the cotton, and is better suited for picking extra long staple cotton.

There is serious need for research to increase picker efficiency and maintain lint quality by providing information in the following areas:

1. Effects of various cotton picker spindle moistening agents on picker efficiency and cotton quality. Preliminary results on this problem reveal interesting facts about the effects of these agents on picker efficiency, but effect on cotton quality has been difficult to detect.

2. The relationship between the relative humidity of the atmosphere (field moisture) and the amount of moisture that should be added to the picker spindles, and the relative effect of these factors on total seed cotton moisture delivered at the gin.

3. The relationship between the methods of handling and storing cotton prior to ginning and such quality factors as amounts of moisture and trash.

Ginning

Numerous problems with respect to the ginning of mechanically harvested cotton remain to be solved. More efficient and effective cleaning machinery needs to be developed. The stick machine previously mentioned is one step in this direction. Better methods are needed for the removal of grass and leaf trash from seed cotton. Methods for cleaning the extra long staple cottons of the American-Egyptian types without fiber damage need to be found, and the entire method of ginning these cottons should be improved.

A solution must be found for the problem gins are encountering in trying to handle greater daily volume of cotton as mechanical pickers compress the harvesting season into a relatively few short weeks. Part of this solution can be found in developing effective methods of storing mechanically harvested cotton at the gin or on the farm without grade loss, seed deterioration, and the high costs now involved.

Better controls for cotton gin equipment are needed to aid in preserving the quality of ginned lint. Better, faster, and less expensive methods for measuring the quality of the cotton are necessary in order for the farmer and ginner to have a better guide for their operations.

These are some of the more pressing problems of ginning research to keep mechanical harvesting economically feasible. Constant research is necessary because changes in operating and harvesting practices, as well as in cotton characteristics, create new problems with which the gin must cope in order to maintain the quality of mechanically harvested cotton.

The Team Approach in Research

These are some of the needs to be filled by future research. Some of the work is already in progress, but many of the final solutions are not in sight. Just when the answers will be found and when they can be put to work is impossible to estimate, partly because of the complex interdependence of one aspect of mechanization upon another. A chemical may be found that will more effectively combat insect or disease losses, but it cannot be used until a method of application is developed. On the other hand, the solving of one problem may speed the solution to others. But with the team approach, research is attempting to increase the benefits of mechanization as rapidly as possible in the interest of the cotton farmer and American agriculture.

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